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EFFECT OF FABRIC DEFLECTION ON CONTROL CHARACTERISTICS

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In the past fabric-covered control surfaces have been widely used on airplanes without noticeable adverse effects. On modern high-speed airplanes, however, several instances have been observed in which undesirable control-force characteristics were attributed to deflection of the fabric on the control surfaces.

In the case of a British pursuit airplane the ailerons, which were originally covered with fabric, became unduly heavy at moderate speeds. In a dive at 400 miles per hour, the heavy control forces so limited the deflection available that about 5 seconds were required to bank 45°. In later models of this airplane, ailerons of the same shape were covered with metal instead of with fabric. This change resulted in a marked improvement in the characteristics, especially at high speed.

Heavy rudder forces in dives have been encountered on two pursuit airplanes having fabric-covered rudders and offset fins. In one of these cases, quantitative measurements were made of the rudder forces and the rudder and the tab deflections in dives. The results of these tests are shown in figure 1. In the power-off condition, at high speed, a left rudder deflection was required to counteract the effect of the offset fin. If the airplane were trimmed to zero rudder force at about 220 miles per hour, rapidly increasing left rudder force was required to maintain trim as the speed increased, in spite of the fact that the rudder and the tab deflections and, presumably, the angle of flow at the tail remained unchanged. This change in force can be attributed only to a change in the shape of the rudder caused by fabric deflection. The force variation with speed was eliminated in later tests by removing the fin offset. This change reduced the rudder deflection for trim and the loads on the fabric that caused the rudder to change shape were thus avoided.

The results of recent tests of an experimental set of elevators for a pursuit airplane are shown in figure 2. These elevators caused a decrease in stick-free stability equivalent to a rearward center-of-gravity movement of 2 percent of the mean aerodynamic chord. The elevators had the same shape as the ones originally fitted to the airplane, but the fabric covering was found to be loose. The decreased stability was attributed to an increased tendency of the elevators to float with the relative wind, which resulted from the effects of fabric deflection.

The magnitude of the fabric deflection in the preceding examples was not measured. One example of the amount that fabric may be expected to deflect under air loads is illustrated by measurements made in dive tests of an obsolete biplane dive bomber (fig. 3). The envelope of fabric deflections measured midway between wing ribs during a gentle pull-out from a dive at a speed of about 260 miles per hour is shown. The effect of the fabric deflection on the section normal-force and pitching-moment coefficients, as determined from pressure-distribution measurements, is given in figure 4. Although these measurements do not indicate directly the control-force characteristics, they show that the effects of fabric deflection may be expected to be appreciable in high-speed flight.

Two examples showing that large effects on control-force characteristics may be caused by small changes in shape similar to the changes that might result from fabric deflection are furnished by recent wind-tunnel tests. It is believed that the fabric on a control surface may in some cases distort to a form which resembles the hook-shape trailing edge illustrated in figure 5, for which the data are taken from figures 2 and 4 of reference 1. This modification adds a practically constant hinge-moment increment of -0.08. If this hinge-moment change occurred on the rudder of the pursuit airplane mentioned previously at an indicated speed of 300 miles per hour, a pedal force of 850 pounds would be required to hold the rudder. Though the shape tested may not be exactly that of the distorted fabric, this example illustrates the way in which small changes in shape of the surface near the trailing edge of the control surface may have relatively large effects on the control-force characteristics of the airplane.

A second type of fabric distortion that might conceivably occur is a bulging of both the upper and lower surfaces due to internal pressure. Figure 6 for which the data are

taken from figures 9 and 13 of reference 2, shows that such a change in shape may completely alter the slopes of the hinge-moment curves.

In the past, the changes in hinge-moment characteristics caused by fabric deflection have not been apparent because of the relatively low speeds of aircraft. In modern high-speed airplanes, however, slight changes in control-surface hinge-moment coefficients, such as may result from small changes in the shape of the surface near the trailing edge, cause large changes in stick and pedal forces; because the controls must be closely balanced, these slight changes in hinge-moment characteristics cause large percentage changes in the control forces that can no longer be neglected.

Little quantitative work has been done on the effect of fabric deflection on control surfaces. It will be realized that the deflection may be affected by factors such as rib spacing, fabric tension, and the method of venting the surfaces. The effect of the fabric deflection on the hinge moments cannot be accurately estimated from available data. In order that control forces of a high-speed airplane be predictable, the use of a type of construction that will insure a higher degree of rigidity of the covering than has been attained in the past on fabric-covered surfaces appears advisable.

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2. Halliday, A. S., Sweeting, N. E., and Skelton, W. S.: Investigation of the Effect of Change of Section on Rudder Hinge Moments. Conf. Rep. 5266, S. & C. 1249, N.P.L. (British), Aug. 14, 1941.

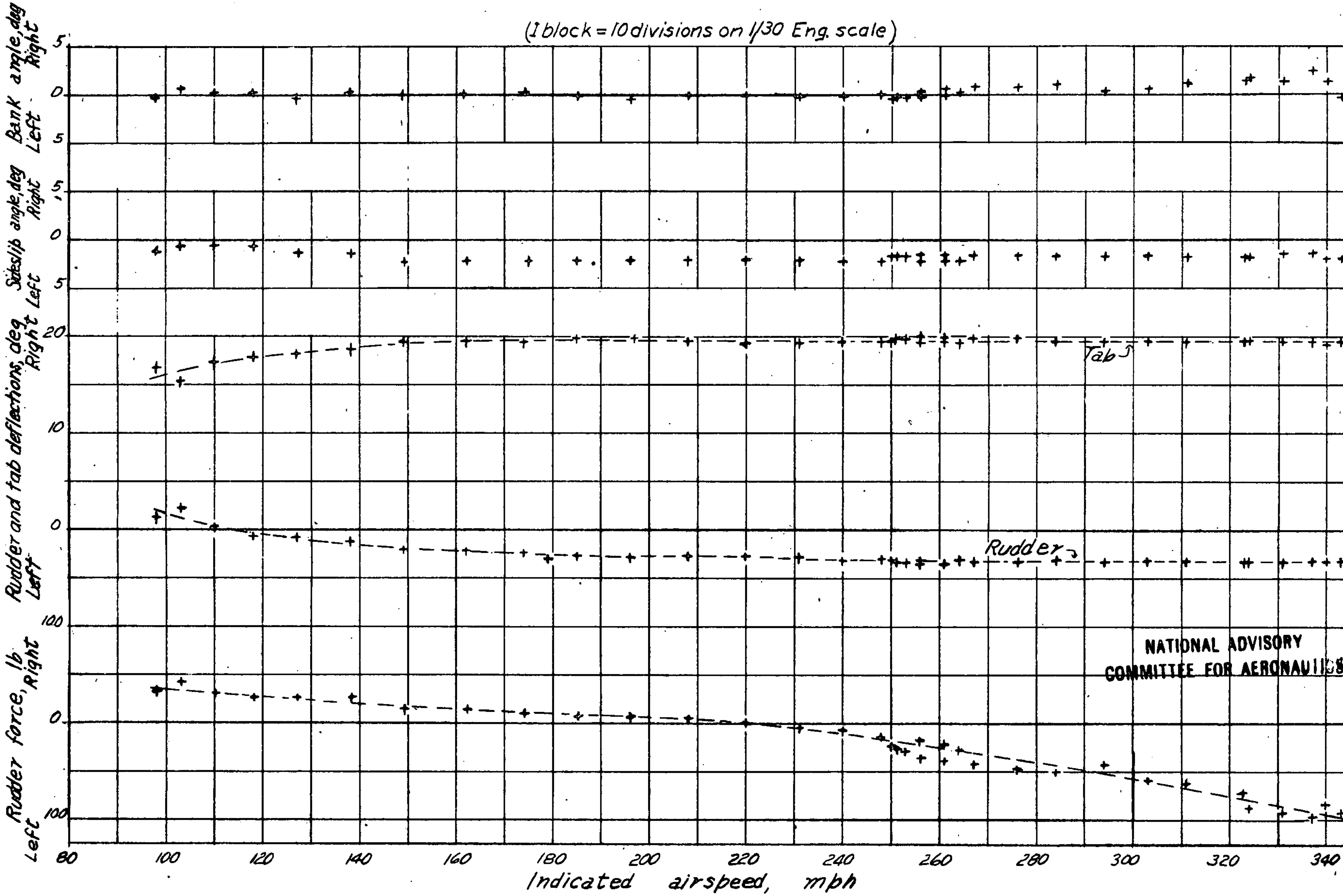

Figure 1.—Directional trim characteristics of a pursuit airplane. Power off, clean condition.

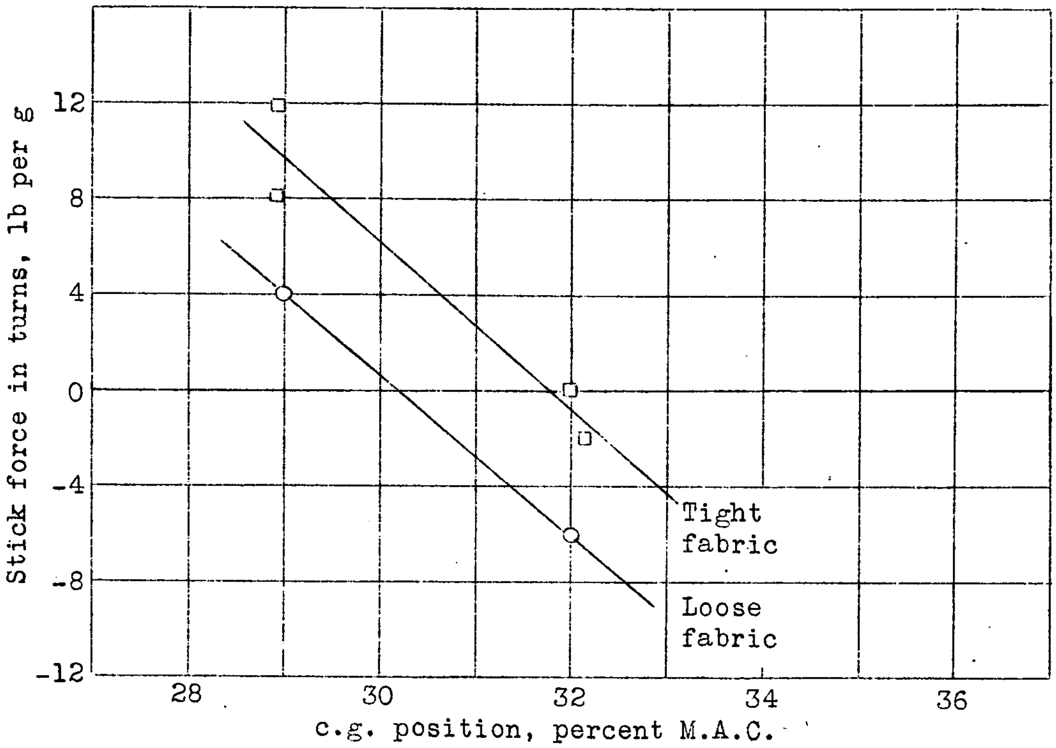

Figure 2.- Effect of fabric tension on the control-force characteristics of a pursuit airplane.

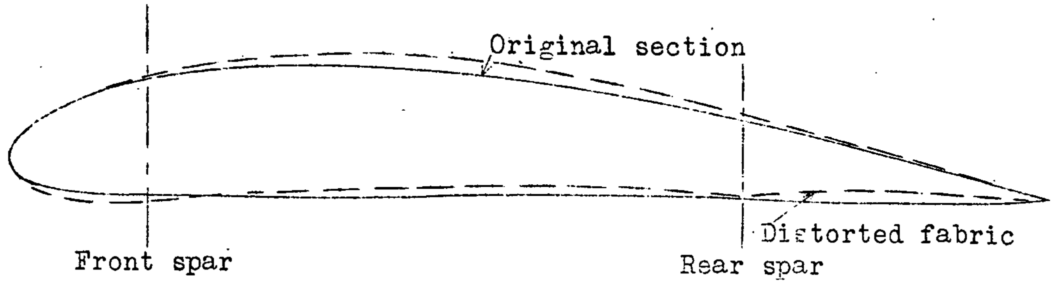

Figure 3.- Envelope of fabric deflections measured midway between ribs on wing of a biplane dive bomber during a pull-out from a dive at a speed of about 260 miles per hour.

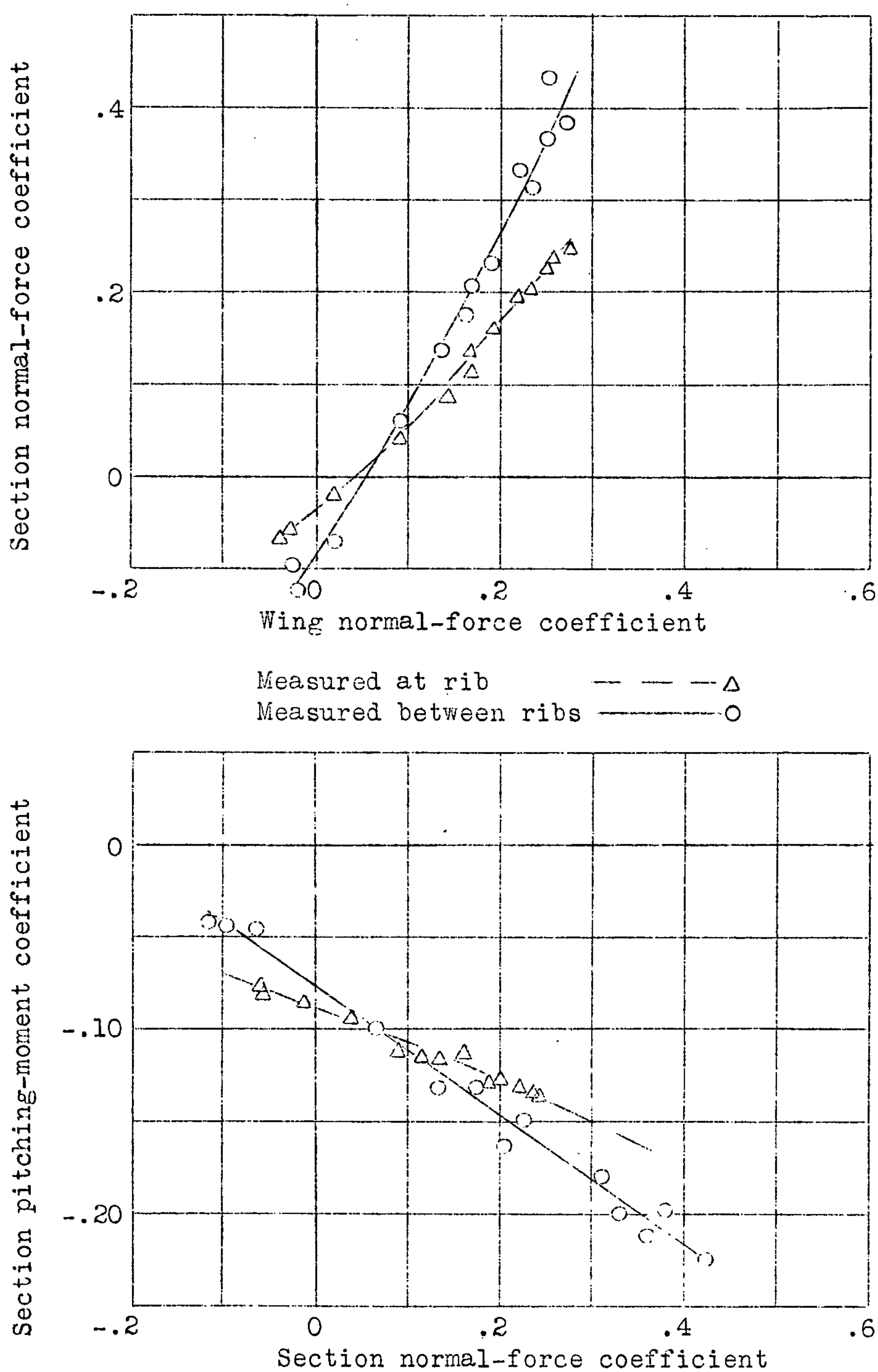

Figure 4.- Comparison of section characteristics obtained from pressure-distribution measurements on wing of biplane dive bomber at a rib and midway between two ribs. Measurements made in dive pull-outs at a speed of about 260 miles per hour.

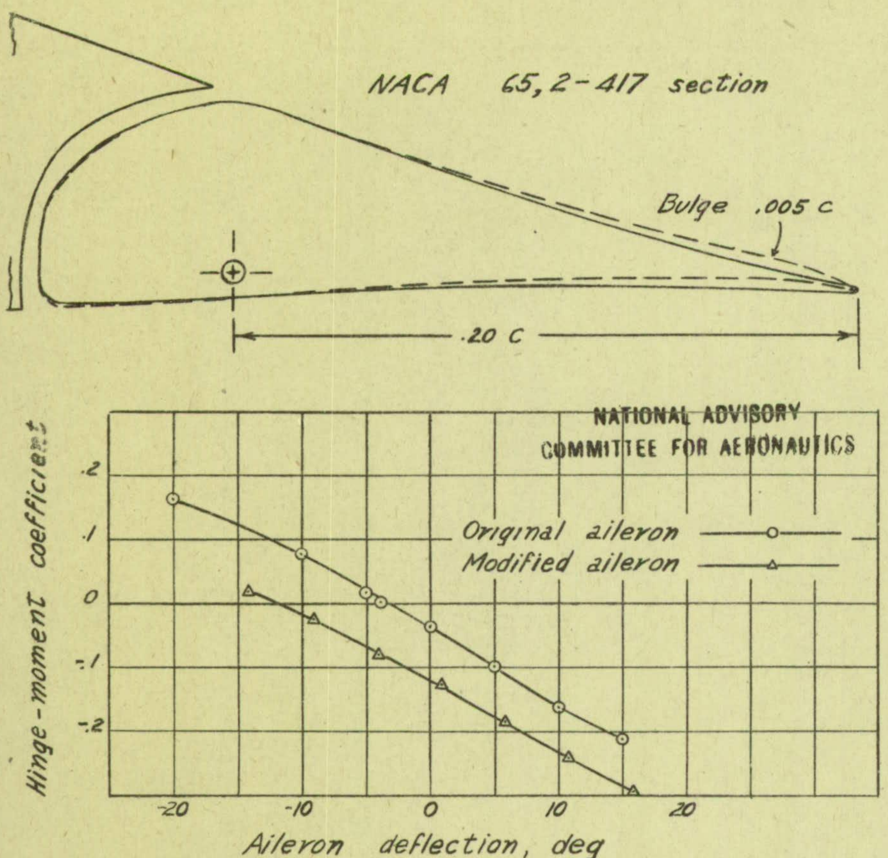

Figure 5.—Effect of a hook-shape trailing edge on aileron hinge-moment chacteristics. (Data taken from figs. 2 and 4 of reference 1.)

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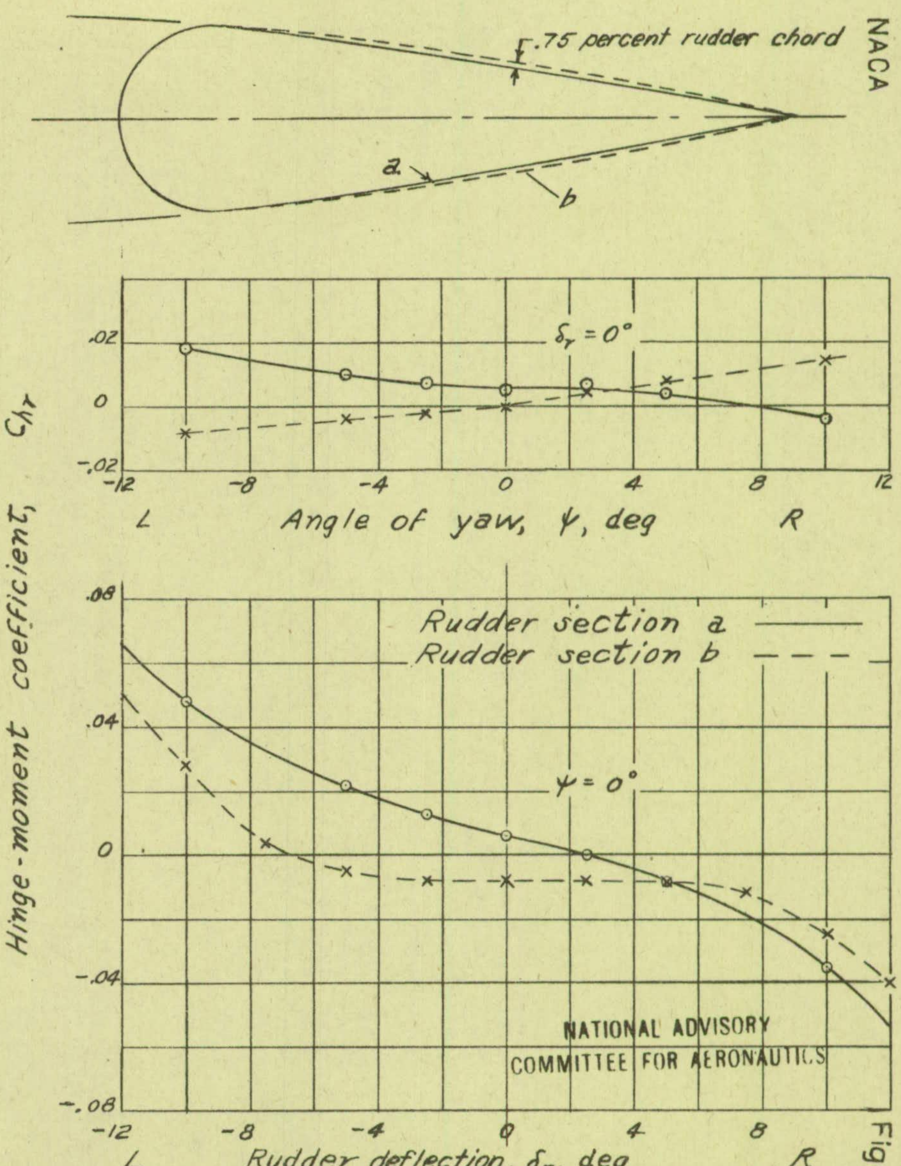

Figure 6.—Effect of change of convexity of the surface of a rudder on its hinge-moment characteristics. (Data taken from figs 9 and 13 of ref. 2).

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Figs. 5,6